VOLUME XL NUMBER 5 WHOLE NUMBER 354

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR, C. A. CHANT ASSISTANT EDITOR, F. S. HOGG

David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS:

R. MELDRUM STEWART
Dominion Astronomer
Ottawa

J. A. PEARCE
Head Astronomer
Dominion Astrophysical Observatory
Victoria, B.C.

J. PATTERSON
Controller of the Meteorological Service of Canada, Toronto

PUBLISHED MONTHLY
(*Ten numbers per year*)

May-June, 1946

PRINTED FOR THE SOCIETY
TORONTO: 3 WILLCOCKS ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XL, No. 5 MAY-JUNE, 1946 WHOLE No. 354

Articles **Page**

What do the Heavens Declare?.....*W. Harvey McNairn* 173

Great Telescopes; and the Planetarium.....*C. A. Chant* 178

Curves of Growth for Neutral and Ionized Atoms in the Spectrum of Alpha Persei.....*K. O. Wright* 183

Review of Publications

Water Adsorption, by Edward Ledoux (*John B. Ferguson*); German for the Scientist, by Peter F. Wiener (*C.A.C.*)..... 201

Notes and Queries

Mount Wilson and Mount Palomar (*C.A.C.*); New Reflector for the Lick Observatory (*C.A.C.*)..... 203

Out of Old Books

The Eruption of Krakotoa, Red Sunsets Telescopic Meteors..... .....*Helen Sawyer Hogg* 205

Meetings of the Society

At Toronto..... 210

Upon request, made previous to publication of article, contributors will be supplied free with twenty-five copies of the sheets containing the article attached to a printed cover.

Extra copies about as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies....	$3 50	$5 50	$9 50	$10 00	$13 00	$16 00
100 copies....	4 00	7 00	10 00	11 00	14 00	18 00
200 copies....	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Address of Editors: David Dunlap Observatory, Richmond Hill, Ontario.

Business correspondence, remittances, etc., should be addressed to J. H. Horning, Treasurer of the Society, 3 Willcocks St., Toronto 2B, Ontario.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

PRINTED IN CANADA

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XL, NO. 5 MAY-JUNE, 1946 WHOLE NO. 354

WHAT DO THE HEAVENS DECLARE?*

By W. HARVEY MCNAIRN

AS far back as written records carry us, we find in them abundant evidence of the belief among the ancients that the stars bear witness to their governance by gods and demigods. Then, later on, when the loftier idea of a solitary Supreme Creator had been achieved, it could be said that "The heavens declare the glory of God, and the firmament sheweth his handiwork."

Since those noble words were written, our knowledge of the universe has been immeasurably expanded, and we now know that it was produced, and its motions are controlled by the laws of Nature. If it were true that all its phenomena could be adequately expressed in a similar naturalistic way, there would be no possibility of a theory of Theism. But we must not accept this conclusion until we have carefully explored the whole situation. In order to do so, we must review the course of evolution of the universe.

A dramatic way of doing this is by conjuring up a series of pictures as of history reversed, and so trace the process step by step to the beginning. This will be like viewing a moving-picture film run backward, an incongruous experience which seems to symbolize a change in the course of time, so that it now runs from the present to the past. So, peering backwards into the abyss of the ages, we see the earth in its primeval condition of a sphere of incandescent gas, similar in almost every respect to a star, but revolving round the sun, which many still believe was the parent of all the planets.

*Address to Hamilton Centre, R.A.S.C., April 15, 1946

The picture changes, and we see the universe before the birth of any planetary system. We must now move farther back in space, so as to include the whole of our galactic system within our range of vision. At this great distance we could see no change except that the stars would be considerably larger. The absence of planets would not be noted. We should be too far away to see them, even if they were present.

Turning our eyes in the other direction, we would see millions of other objects, which would be either spiral swarms of stars, or glowing spheres of gas which are flattening out in the process of becoming spirals.

The moving film turns backward to an earlier exposure. At this time the temperature is higher, and gas particles are moving at tremendous velocities. Their numerous collisions would hurl them ever farther apart. The spirals and even the gaseous, giant spheres have not yet appeared. Space now contains nothing but flying atoms. This is the primordial chaos that the ancients wrote about.

They thought that there could be nothing simpler, but we now know that the atom is not the primary unit of matter. It is a complex thing, made up of smaller constituents, protons, neutrons and electrons. The chaos of atoms could not have been the primal condition of things. There must have been a still earlier chaos of particles. Now these minute objects are merely immaterial vibrations, and it is inconceivable that they always existed. They must have had a beginning. So when we view the earliest exposure of all, we find that there is nothing but space.

What then is space? It is definitely not mere nothingness, for it has properties. To begin with, there are the three familiar dimensions, length, breadth and thickness. Also the theory of relativity shows that there is a fourth dimension, that we call time. Now nothingness can have no dimensions.

Another deduction from relativity is that there is no such thing as a straight line in space. In order to test this by observation, the apparent position of certain stars that are so situated that they would normally be seen close to the sun's disc if they were not obliterated by the sun's light rays, was determined during a total eclipse. They then appeared to be closer to the disc than their calculated normal position. The ray of light had been deflected by the force of gravity.

Similarly, all lines in space, and all moving objects must be deflected towards the centre of gravity of space.

Now mathematical analysis shows that gravitation itself depends upon the properties of space. It is the most mysterious force in Nature. All others, except perhaps magnetism, require actual contact. Even radio transmission, which also seems mysterious, results from unit particles of energy, the quanta, travelling with the speed of light. Gravity, on the other hand, seems to act instantaneously across space. Relativity explains this, as due to the curvature of space in the fifth dimension around any object that has mass, just as, to use a crude illustration, thin ice sinks around a stone that rests upon it, forming a slope down which a smaller pebble will slide.

Also it appears that space has the property of causing the immaterial vibrations that constitute light, and that are called photons. Now, atomic particles are also immaterial vibrations, and as far as one can tell, are essentially of the same nature, differing, perhaps, only in the intensity and direction of the vibrations. Thus light and matter alike, seem to be the offspring of space. It would thus appear that the whole material universe, including man, was potentially present in space before the first vibration started, and evolution did the rest.

If we stopped here, it might seem that space is eternal and self-existent, and therefore must be the ultimate reality. If so, we need seek no further for an explanation of existence, knowing that the mystery is unfathomable. But here a difficulty appears at once. We are sure that the material universe is not eternal. It had a beginning and some day will have an end. An estimate of its age is possible on the basis of the rate of radioactive decay of certain elements in the rocks. Now, if the nature of space is such that it inevitably gave rise to the material universe, which, as we have seen, did not always exist, then, either space did not always exist, or there was some inhibiting force that retarded its action until a measurable time ago, which is manifestly incredible.

This leads to the conclusion that space itself must have arisen a measurable time ago, which in turn raises the problem of its origin. When we attempt to penetrate this deeper mystery, we can no longer depend upon scientific induction, for there are no verified facts upon which to base our theories. We must therefore fall back upon the

less convincing method of deductive reasoning. From the purely naturalistic point of view, there would appear to be but three alternative answers. Space may have originated either by chance, by fate or by necessity. Let us therefore consider each of these in succession, to see if they can give us any guidance in our investigation.

The idea of chance immediately arises. Many of the ancient cosmogonies are based upon it, and it still maintains its influence upon modern thinking. What then do we mean by chance? When something occurs for which we can assign no reason, we say that it just happened. This may be merely a confession of ignorance. We do not know why it occurred. Or, more philosophically, it was an uncaused event. Chance may therefore be defined as the occurrence of uncaused events. When we attempt to apply this reasoning to the origin of space, we are faced with a new dilemma. An event is an occurrence at some particular point and at a given moment of time. In other words, it is a phenomenon of space. Apart from space, there can be no events. Therefore, to say that space arose by chance, is the same as supposing that it is due to forces that did not exist until after the event, which is absurd.

The idea of an inexorable fate that governs the actions of men as well as the course of events, is another concept that appears again and again, especially in oriental philosophy. Fate must not be thought of as intelligence, else it must be God. It is merely an eternal design without a designer. If this is hard to understand, there is a corollary that is still more difficult. Fate must be eternal and uncreated, and yet for endless ages in the past it could not function. It was like a blueprint filed away until time should start and space be formed. Such a conception is incredible, though not necessarily untrue. In any case, there are no possible proofs to support it, and so it must be discarded.

When we turn to the third alternative, necessity, we seem to be on firmer ground. We think of this as Natural Law. We say, in the nature of things, a certain result must follow a given combination of forces. May it not be that if we knew all the laws of nature, the origin of space would present no difficulty whatever? But what do we mean by the laws of nature? Are they not merely a statistical interpretation of the course of events, an attempt to reach a conception

of ultimate reality? There is, we believe, a certain ordered regularity in the events that we observe in the universe. But when we attempt to find in them the cause of the existence of space, they fail us. Before space arose, there were no events and no laws of nature, since there was no nature. It is the previous dilemma of attempting to explain the origin of space in terms of the properties of space itself.

We now come to the conclusion that space is not eternal and therefore cannot be the ultimate reality, and that it cannot be explained in terms of chance or fate or natural law. Yet that there is a design in nature is clearly indicated in many ways, for instance by the extraordinary properties of some of the elements. Can we conceive of a design without a designer? Some philosophers claim that this is possible. But there is a well-recognized rule in philosophy that says that of any two alternative explanations of the same phenomenon, that one is to be chosen that is the simplest. In the present case, the theory that involves us in the fewest difficulties, is that there is not only a design in nature, but that this design, in the words of Bishop Berkeley, "arises from the subsistence" of the laws of nature "in the mind of some Eternal Spirit."

Now this conclusion must not be considered as lending its support to the theory of Theism. As Jeans points out, as far as astronomy can discover, three qualities that we admire in the most highly developed human minds, emotion, morality and esthetic appreciation, are not exhibited by the Creator. Theism, on the other hand, is based upon the belief that the Creator not only has these qualities, but also goodness, justice and an interest in the welfare of his creatures. While it stands to the credit of astronomy that it supplies the basic concept of a Supreme Creator, we must look elsewhere for indications of some of his attributes. The poet finds this nearer home than the stars:

> A fire-mist and a planet,—
> A crystal and a cell,—
> A jelly-fish and a saurian,
> And caves where the cave men dwell;
> Then a sense of law and beauty,
> And a face turned from the clod,—
> Some call it Evolution,
> And others call it God.

Dundas, Ont.

GREAT TELESCOPES; AND THE PLANETARIUM*

By C. A. Chant

I. Great Telescopes

THERE are two types of telescopes,—refractors or lens-telescopes, and reflectors or mirror-telescopes. In the former, a lens at the end of a tube converges the light from an object in the sky, to which the tube is pointed, to form an image of that object; in the latter, a concave mirror does the converging. In both cases another lens, known as an eyepiece, is used to examine the image.

The two greatest refractors in existence are at the Lick Observatory on Mount Hamilton, California, and the Yerkes Observatory at Williams Bay, Wisconsin. They are portions of the equipment of the University of California and of the University of Chicago, respectively. The lens of the Lick telescope has a diameter of 36 inches and the tube is over 56 feet long; in the Yerkes instrument the diameter is 40 inches and the length over 65 feet. Needless to say, both instruments are of the highest class, optically and mechanically.

It is believed that the 40-inch telescope is as large a refractor as is practically possible. The critical reason for this limitation in size is that the two component lenses which together make up the complete lens are thin and delicate, and when the telescope is moved about to point at different objects up and down in the sky, if made larger these components would be distorted and the image produced would be imperfect.

But astronomers demanded larger instruments in order to examine fainter objects in the depths of space, and so they turned to reflectors. Mirrors having diameters much greater than 40 inches were possible; and, further, mirror-telescopes are much better for taking photographs of celestial objects than are lens-telescopes. The largest reflector now in use is on Mount Wilson in California and is 100 inches in diameter; the next in size, diameter 82 inches, is at the McDonald Observatory at Fort Davis in Texas; while the third, of diameter

*A condensed account of an address to the Arts and Letters Association of Clearwater, Florida, February 19, 1946.

74 inches, is at the David Dunlap Observatory of the University of Toronto.

With the 100-inch telescope some very notable investigations have been made into the nature and the distance of spiral nebulae. Convincing evidence has been obtained that these faint bodies are in reality great units such as our Milky Way and all the stars which we can see. These comprise our galaxy. (Remember that these stars are suns.) The most distant galaxies which we can photograph with the 100-inch are estimated to be 500,000,000 light-years away, and one light-year is approximately 6 million million miles. Nearly twenty years ago the Mount Wilson Astronomers felt that they had reached the limit of their great telescope, and about 1928 appealed to the Rockefeller General Education Board for funds sufficient to produce an instrument with a mirror 200 inches in diameter, with which it is believed space to twice the previous depths can be explored. The sum of $6,000,000 was allotted for the purpose and the monster instrument is now almost completed. The site for it is on Mount Palomar, between Pasadena and San Diego. Within the next decade some striking results will surely be obtained with this great engine of research.

II. The Planetarium

In these days when the word planetarium is mentioned one thinks of the complicated instrument devised by the firm of Zeiss for representing the appearance of the heavens. However it has a much wider meaning and includes any apparatus for exhibiting the motions or the appearance of the celestial bodies.

There is a legend that Archimedes constructed a model of this sort, but of its nature we are entirely ignorant. The first instrument to exhibit the motions of the bodies of the solar system of which we are fully informed was made by van Ceulen, an eminent clockmaker at the Hague in 1682. In computing the gear-ratios and in the general design he was assisted by the distinguished Dutch scientist Huygens, the contemporary and friend of Isaac Newton. The machine was well built and is still preserved in Leyden. Soon after 1700 George Graham, the inventor of the mercury pendulum, constructed a model for Prince Eugene; and a little later an improved form of it was supplied by John Rowley to Charles Boyle, fourth Earl of Orrery. To

this instrument was given the name "orrery" by the essayist Steele, and such these mechanisms have been commonly called ever since.

Many other models have been constructed. In the Deutsches Museum in Munich in 1920 there was installed a model of the solar system out as far as the planet Saturn, in which the various planets revolved at the proper relative speeds. The orbit of Saturn in it is 30 feet in diameter. For Uranus, the next planet, the orbital diameter would be 60 feet. Hence this and the remaining planets are not included. A platform is attached to the earth on which the visitor may ride and thus observe the motions of the other bodies relative to the earth, as of course we must do in nature.

In such models usually no attempt is made to represent the stars. We are all familiar with the ordinary celestial globes, on which the sky, with its constellations, its celestial equator and poles and meridians are exhibited, but unfortunately they are not as in nature, but reversed. We actually see the sphere of the sky from within, apparently from its centre, while we examine the model from the outside.

Hollow celestial globes have been conceived and produced by several persons. About 1758 Roger Long, the first Lowndean Professor of Astronomy and Geometry at Cambridge, constructed a sheet-metal sphere 18 feet in diameter. It was pierced to represent the stars and was illuminated from the outside. Thirty people could be accommodated on a platform within it and it could be rotated by hand from outside. It was in existence until 1874.

A notable improvement on all previous models was designed in 1911 by Wallace W. Atwood, secretary of the Chicago Academy of Sciences, afterwards president of Clark University, and it was completed in 1915. It is of sheet-metal and its diameter is 15 feet. It is driven by an electric motor controlled from the platform inside. The stars are represented by holes of appropriate sizes in the metal sphere which is illuminated on the outside, and the sun is shown by an electric light which is movable along the ecliptic. This instrument obtained a wide reputation, and von Miller approached the firm of Zeiss regarding a similar apparatus for the Munich Museum. The firm did much computing and experimenting but did not reach a satisfactory solution. Then in 1919 Bauersfeld, one of their engineers, made the proposal to erect a large hemispherical dome and place at its centre an optical projector which would cast on the inner surface of the dome the

various astronomical phenomena observed in the sky. The complicated apparatus was completed in 1924 and proved a great success. Even those who designed it were surprised at the result. Astronomers and museum men went to Jena to inspect the new instrument and they were all enthusiastic over it. The usual model one sees is so crude and imperfect compared with the majestic spectacle of the sky, but here was a perfect and thrilling exhibition of the heavens. The general testimony of praise is well illustrated by the opinion expressed by the well-known astronomer E. Stroemgren of Copenhagen:

> Never has a means of entertainment been provided which is so instructive as this, never one which is so fascinating, never one which has such general appeal. It is a school, a theatre, a cinema in one; a school-room under the vault of heaven, a drama with the celestial bodies as actors.

For this modern planetarium the dome is usually 65 to 80 feet in diameter, painted white on the inside, and at the centre is the great projecting machine. This is shaped like a dumb-bell about 12 feet long over all, the "spheres" at the ends being 29 inches in diameter, the connecting "bar" about 18 inches. It is mounted so that it may be rotated about various axes.

The starry background is produced by 16 separate projectors attached to each of the end spheres—32 in all. The "lantern slides" are plates of copper about 1/1,000 inch thick, in which holes of proper sizes have been punched by hand. The smallest, to show the faintest stars visible to the naked eye, are 9/10,000 inch in diameter; the largest, 3/100 inch; and there are 9,000 stars in all. The source of light is a 1,000-watt lamp at the centre of each of the 29-inch spheres; i.e., one lamp supplies the light for the 16 projectors attached on that sphere. The lenses for these projectors are of the "Tessar" type used in high-class cameras. The magnification is 80, so that the brightest star is represented on the dome-screen as a bright spot 2.4 inches in diameter. Sirius, the Dog Star, is so bright that it has a separate projector, as also has each of the variable stars, Algol, Mira, and Delta Cephei.

By rotating the instrument about the proper axis the stars rise in the east, cross the sky and set in the west, and by simple mechanical means they are made to fade out gradually as they come near to the horizon. Attention to little details like this gives an impression of absolute reality.

In order to show the appearance and the motions of the planets the mechanism is much more complicated. Mercury, Venus, Mars, Jupiter and Saturn require two projectors each. To show the sun and its various phenomena 7 projectors are used, and for the moon there are two. In all, there are 105 projectors, which are fed by 33 electric lamps.

Five of these Zeiss planetariums are in the United States—located at Chicago, Los Angeles, New York, Philadelphia and Pittsburgh.

The cost of the projecting outfit at first was RM 300,000, £15,000, $75,000. It can hardly be quoted now. Some of the patents on the apparatus have expired and possibly variations of the machine may be produced in the United States or some other country. The dome may be constructed in different ways, at different costs.

The Adler planetarium at Chicago, the first in America, commenced operation in 1930, with the distinguished astronomer Dr. Philip Fox as director. In describing the planetarium he says:

> The visitors come to see a stirring spectacle, the heavens brought within the confines of museum walls. Not a trivial plaything, a mimic aping firmament, but the heavens portrayed in great dignity and splendour, dynamic, inspiring, in a way that dispels the mystery but retains the majesty.

CURVES OF GROWTH FOR NEUTRAL AND IONIZED ATOMS IN THE SPECTRUM OF ALPHA PERSEI*

By K. O. Wright

ABSTRACT.—Curves of growth for atoms in the spectrum of α Persei have been constructed from measures of equivalent widths obtained from high-dispersion spectrograms, combined with solar *f*-values. The observations indicate that the curves for neutral atoms are different in shape from those for ionized atoms, and also that theoretical curves may not represent the observations completely. The fit of the observations on theoretical curves of growth indicates that the temperature may be lower, the pressure lower, and the turbulent velocity greater, for ionized than for neutral atoms. These results suggest a stratification in the atmosphere of this supergiant star, with the mean position of the ionized atoms above that of the neutral atoms.

CURVES of growth for α Persei have been obtained by O. Struve and C. T. Elvey,[1] T. Dunham, Jr.,[2] Miss H. R. Steel[3] and the writer.[4] The present results are based on new equivalent-width measures of high-dispersion spectra taken at Victoria. The study was begun in an effort to show that a well-defined curve of growth may be drawn when accurate equivalent widths are plotted against solar *f*-values. α Persei was chosen as a test object because, in previous work, the observed scatter about a mean curve of growth was greater than that for α Canis Minoris or γ Cygni. It was also chosen because it is a supergiant star of spectral type F5, and, as Struve[5] has pointed out, a detailed study of the curve-of-growth phenomena in this type of star may prove important in the explanation of Cepheid variation.

The Observations

The observations are based on high-dispersion spectrograms taken with the 72-inch telescope of the Dominion Astrophysical Observatory. For the region λλ3700-4500, the third order of a

*Contributions from the Dominion Astrophysical Observatory, No. 2.

[1] *Ap. J.*, vol. 79, p. 409, 1934.

[2] *Mount Wilson Annual Reports*, p. 149, 1933-1934.

[3] *Ap. J.*, vol. 102, p. 43, 1945.

[4] *P. Am. A. S.*, vol. 10, p. 338, 1944.

[5] *Observatory*, vol. 65, p. 257, 1944.

Wood aluminum-on-glass grating was used in a Littrow mounting; the second order of the same grating was used for the region λλ5150-6750; and the three-prism spectrograph was used, for comparison purposes and to cover the remaining region, from λλ4020-5600. The dispersions given by these three instruments are 4.4. A/mm., 7.0 A/mm. and from 4.8 A/mm. at λ4020 to 19 A/mm. at λ5600, respectively. Corrections for Rowland ghosts in the grating spectra were determined by photographing a mercury arc in the violet, and a neon discharge tube in the red. The sum of the ghost lines was found to be 8.0 per cent. of the main line for the third order and 3.7 per cent. for the second order. The corrections were applied in the usual way[6] by raising the zero point on the intensity tracings by these amounts.

Two or three plates of the spectrum covered by each instrument were run through the microphotometer. Calibrations impressed upon the plate using a small-scale spectrograph and rapidly rotating sector were placed upon the tracing every two hundred angstroms. Later, the intensitometer designed by Dr. C. S. Beals[7] was used to transform galvanometer deflections into observed intensities and to rectify the continuous spectrum. As it is used now, several tracings, with a total magnification over the original plate of two hundred-fold, may be superposed; thus many errors inherent in photometry, such as plate grain and inaccuracies in drawing the calibration curves and in determining the position of the continuous spectrum, may be averaged and a mean profile for each line may be sketched immediately.* The profiles of over one thousand lines — those that were strong enough to measure and were free from blends, or where the effect of the blending line could be estimated readily — were drawn and the areas were measured with the planimeter. Identifications were made with the aid of Dunham's "Spectrum of Alpha Persei,"[8] and the *Revised Rowland Table of Solar Wave-lengths*.[9] These were checked and additional identifications were made when Miss Moore's "Revised Multiplet Table"[10] was received.

[6]Minnaert, *Z. f. Phys.*, vol. 45, p. 611, 1927.

[7]*J.R.A.S.C.*, vol. 38, p. 65, 1944.

*A more detailed account of spectrophotometric techniques is given in *P. Dom. Ap. O.*, Victoria, vol. 7, No. 20, now in preparation.

[8]*Cont. Princeton O.*, No. 9, 1929.

[9]St. John et al, *Papers of Mount Wilson O.*, vol. 3, 1928.

[10]*Cont. Princeton O.*, No. 20, 1945.

The equivalent widths measured on overlapping regions of the spectrum were intercompared. No serious systematic errors were detected between one region and another, or between prism and grating. Therefore, for unblended lines, the values used in this study are the simple means of from two to five plates over the region λλ3700-6750. A comparison with Miss Steel's measures[3] shows that her intensities are some 25 per cent weaker than the Victoria values for the stronger lines. Lines within the wings of the very strong hydrogen lines were not used if the intensity of the hydrogen wing at that point was 80 per cent, or less, of the continuum. For lines farther out in the hydrogen wings, Thackeray's simple relation[11] that "the observed intensity of a blended line is reduced in proportion to the intensity within the blending line" was used; this relation is not exact, but it seems to fit the observed intensities for the sun moderately well.

The Curve of Growth

The curve of growth relates the observed intensity of an absorption line and the "number of active atoms," N, which produce the line. Menzel[12] has shown from theory that log W/λ should be plotted against log X_o where W is the equivalent width of the stellar line; λ, the wave-length; and X_o the optical depth at the centre of the line, is given by

$$\log X_o = \log g_i f + \log \lambda - \frac{5040}{T}\chi_i + \log \frac{N_a}{b(T)} \frac{\pi\epsilon^2}{mc} \frac{1}{\sqrt{\pi}v} \qquad (1)$$

where g_i is the statistical weight of the line, f, the oscillator strength, T, the excitation temperature, and χ_i the excitation potential of the lower level of the atomic transition. The last term, which we shall call C, is a constant for an atom in a given stage of ionization and is proportional to the number of atoms in that stage, N_a; it includes atomic constants and quantities which can be calculated from theory.

In a previous paper,[13] the writer determined a curve of growth for the sun with the aid of equivalent widths measured by Allen,[14] and by himself from the Utrecht *Photometric Atlas of the Solar*

[11] *Ap. J.*, vol. 84, p. 433, 1936.
[12] *Ap. J.*, vol. 84, p. 462, 1936.
[13] *Ap. J.*, vol. 99, p. 249, 1944.
[14] *Mem. Comm. Solar O.*, Canberra, No. 5, 1934; No. 6, 1938.

Spectrum,[15] combined with laboratory $g_i f$-values of neutral iron and titanium, measured in absorption by A. S. and R. B. King.[16] It was found that temperatures of 4900°K for Fe I and 4550°K for Ti I represented the observations best; it was suggested that a temperature of 4700°K was the best available estimate of the solar excitation temperature for other atoms. X_f is the designation which was given to optical depths taken from this solar curve of growth; these values are the basis for the present investigation.* Accurate laboratory intensities for other atoms are needed very greatly; a few atoms are being studied by R. B. King[17] at Mount Wilson Observatory but until these and other results are published, it seems that the solar X_f-values are the most accurate quantities proportional to N which are available for the study of stellar curve-of-growth phenomena.†

Given the equivalent widths for all lines of a certain atom which are observed in a star, and the corresponding X_f-values for the sun, an empirical curve of growth and the excitation temperature for that atom may be obtained. By subtracting the solar values for the data given in equation (1) from those for the star, it is found that

$$\log X_* = \log X_f - 5040\ \chi_i \left(\frac{1}{T_*} - \frac{1}{T_\odot}\right) + (C_* - C_\odot) \qquad (2)$$

[15] By Minnaert, Mulders and Houtgast, Amsterdam, 1940.

[16] *Ap. J.*, vol. 87, p. 24, 1938.

*The actual X_f-values used here for each line were obtained by taking the solar log W/λ and reading off the corresponding X_f-value from a curve similar to that described above, except that an empirical slope of 0.6 rather than the theoretical slope of 0.5 was used for the damping portion of the curve; a better representation of the strong iron lines was obtained by this change.

[17] *Mount Wilson Annual Reports*, 1939-42.

†In a letter of Feb. 8, Dr. Struve draws attention to the theoretical difficulty that "the continuous absorption coefficient in the sun is probably different from that in a supergiant star. As this coefficient (varies) with wave-length, if it is materially different in the two stars, the solar X_0's would not give correct results for the star. . . . It might be useful to point out this difficulty so that workers in this field would exercise caution when they apply solar X_0's to lines of early type stars". An attempt to detect such a difference was made by the author by studying the lines of neutral iron for any change in the curve of growth with wave-length. No difference was detected and, as Dr. Struve suggests, this may be taken as a "somewhat indirect proof that the wave-length relation with the coefficient of continuous absorption is about the same in α Persei and in the sun".

where X_*, T_* and C_* refer to the star, and X_f, $T_\odot$ and $C_\odot$ refer to the sun. For each atom, the lines may be separated into groups of approximately the same excitation potential; since, within such a group, log X_* differs from log X_f by only an additive constant, log W/λ is plotted against log X_f for each set of lines. The curve of growth is formed by sliding each such plot over the others, back and forth along the X_f-axis until the best fit is obtained.

The temperature is determined as follows: As $(C_* - C_\odot)$ is a constant for a given atom, it is seen from equation (2) that a straight line should result if (log X_* − log X_f) is plotted against χ_i; the slope is 5040 $(1/T_* - 1/T_\odot)$ and, as $T_\odot$ is known from previous work,[13] T_*

TABLE I. Excitation Temperatures Calculated from Empirical Curves of Growth for Atoms in the Spectrum of α Persei

Atom	T_* °K	No. of Lines	Atom	T_* °K	No. of Lines
Fe I...	4700	325	Fe II	4400	60
Ti I ...	5650	53	Ti II	4800	62
Cr I...	5600	29	Cr II	5450	25
Ni I...	5250	54	Sc II	5450	22
Ca I...	5550	30	Y II	6200	16
Mn I ..	3900	23			

may then be calculated. When the plots for each set of lines of a given atom have been superposed to give the best fit, then (log X_* − log X_f) is the shift of the plot for some given excitation potential from that for a standard position, such as that for $\chi_i = 0$. As an example, consider Figure 2 which represents the determination of the excitation temperature of neutral iron by this method. All lines shown in Figure 1a were grouped into ten ranges of excitation potential and plots between log W/λ and log X_f were made for each group. The position of log $X_f = 0$ in Figure 1a was taken as standard. The difference between the position of log $X_f = 0$ for a given excitation potential and the standard position is given by the ordinate in Figure 2; the circles on the diagram represent these differences and their size is a measure of the number of lines plotted on each graph. The straight line, which was determined by least squares, has a slope of −0.040; setting $T_\odot = 4900$,° the value for neutral iron, then T_*

for neutral iron lines in α Persei becomes 4700°K. The probable error of this determination is ±150°.

Curves of growth for α Persei were drawn for the atoms listed in Table I. The tabulated temperatures were obtained by least-squares calculations. As each curve was derived independently, any large differences between atoms should be brought out, but it

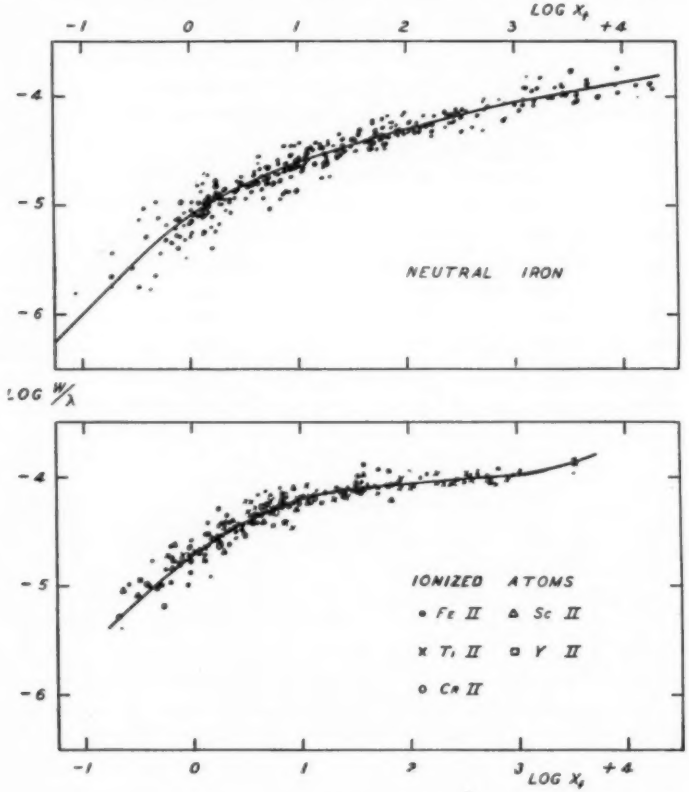

Fig. 1.—Empirical Curves of Growth for α Persei. a (above): All individual observations for Neutral Iron are shown, together with the best curve which can be drawn through normal places of the observations.

b (below): Individual observations and the mean curve for Ionized Atoms. The plot for each element has been shifted horizontally to produce a minimum scatter about the curve.

may be noted from the number of lines listed in Table I that the results cannot be considered definitive except for Fe I, Fe II and Ti II. However, when the mean curves for each atom were superposed, it was observed immediately that all curves for neutral atoms were similar, within the errors of determination, as were the curves for ionized atoms. The neutral and ionized atoms, however, appeared to give curves which were somewhat different in shape.

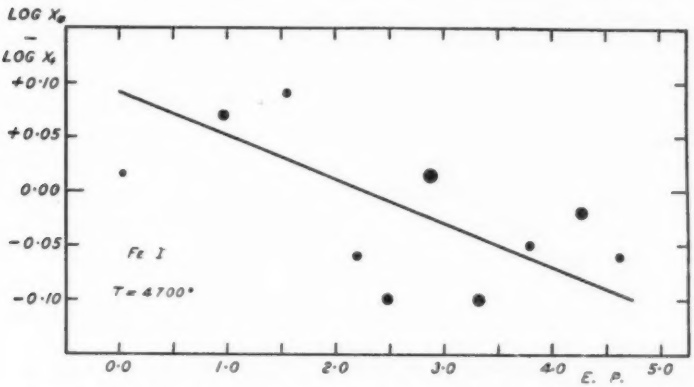

Fig. 2.—The Excitation Temperature of Neutral Iron in α Persei. A least-squares solution was made to determine the straight line; the slope corresponds to a temperature of 4700°K.

The curve of growth for neutral iron, drawn for a calculated temperature of 4700°K is shown in Figure 1a. The scatter of individual points about the mean curve is satisfactorily small and compares very favourably with other published curves. It is quite similar in shape to that given by Miss Steel;[3] the scatter is slightly less than that for her curve, which was plotted for a temperature of 4400°K; it is based on a larger number of lines (325 compared with 200); and it covers a range of 5.5 in log X_f compared with 4.0. This extension is due largely to the addition of the strong neutral iron lines in the ultra-violet. The temperature of 4700° was calculated by determining the best straight line which could be drawn when (log X_* − log X_f) was plotted against χ_i, as indicated above, from the data shown in Figure 2.

Figure 1b shows the mean empirical curve of growth for the ionized atoms, Ti II, Fe II, Sc II, Cr II and Y II. The curves

were determined independently at first but were superposed later; this curve was drawn to indicate the best mean fit for these atoms. Again it may be noted that the individual points cluster closely about the curve in most cases. As even the weakest lines plotted here are well-defined, some weight must be given to all portions of the curve. The upper end of the curve, though based on only two Ti II lines, λλ3759 and 3761, which are blended in the sun, seems to indicate the beginning of the damping portion of the curve.

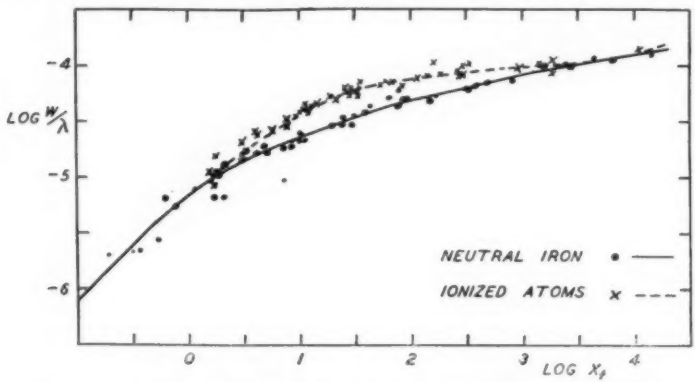

Fig. 3.—Comparison of Empirical Curves of Growth for Neutral and Ionized Atoms in the Spectrum of α Persei. The plotted points represent normal places of the observations shown in Figure 1, and the two curves have been superposed to fit at the two ends.

The shapes of the curves as they are drawn in Figure 1 are appreciably different, but the possibility that this effect is fortuitous must not be overlooked. Figure 3 has been drawn to show the apparent difference in its most marked aspect: the two curves have been superposed to come together for the weakest and the strongest lines. The closed circles represent normal places for the neutral iron lines; the crosses represent mean positions for lines of the several ionized atoms. The latter are well above the neutral-atom curve over most of the range. A better fit between these curves could be obtained by sliding the curve for ionized atoms along an additional 0.4 in log X_f; but even then the mean points for the ionized atoms are all below the neutral-atom curve at the ends of the curve, and are above the same curve for the central portion. A change in the adopted

temperatures for each atom will improve the agreement slightly, but cannot change the general representation.

If, as the above results seem to indicate, there is a real difference in the shape of the curve of growth determined for neutral and ionized atoms, it is desirable to study the effect and its possible causes. As the X_f-values are derived from a solar curve of growth, the observations could represent a difference in conditions between the sun, which is a dwarf star, and α Persei, which is a supergiant. Since the solar curve is based on intensities of only neutral iron and titanium lines, it is possible that the ionized atoms in the sun might produce a different curve, in which case the adopted values of log X_f would be invalid for such atoms. A positive answer to this suggestion cannot be given at present; the only modern laboratory intensities for lines of ionized atoms which are known to the writer are those published by R. B. King[18] for Ti II in the region $\lambda\lambda$ 3143—3761, and there are not sufficient solar intensities available to construct this curve of growth. However, theoretical intensities were calculated for the transition array, $3d^3$-$3d^24p$ of Ti II. These values were combined with the intensities of 38 lines in the sun and 25 lines in α Persei to form curves of growth. Although the scatter in each case is rather large, no systematic deviation from the observed curves could be detected: the solar curve followed that for neutral iron and titanium; on the other hand, the observations of Ti II in α Persei followed the curve for the ionized atoms. In order to compare the solar X_f-values with laboratory g_if-values, the latter were used to plot a curve of growth for α Persei using neutral iron lines. This curve is very similar to that of Figure 1a except that it does not extend to lines weaker than log $X_f = 3.0$; the last point is considerably below the curve, but is based on the line λ4483, the f-value of which King labelled "uncertain." These observations indicate (1) that the solar curve of growth is very similar for neutral and ionized atoms; and (2) that the difference in the curves for neutral and ionized atoms in α Persei arises in the observations of the star and not in the method and assumptions used in plotting the points.

[18] *Ap. J.*, vol. 94, p. 27, 1941.

Discussion of Curve-of-Growth Phenomena

The theory of the curve of growth has been given by Menzel[12] and by Unsöld.[19] Menzel's notation has been used in this paper, modified where necessary to agree with recommendations of the International Astronomical Union.[20] It can be transformed to that used by Unsöld by setting the latter's R_c, the absorption at the centre of a line, equal to unity.* As this value is about 0.95 for the sun, and, from rough estimates, seems to be very nearly the same for α Persei, the discussion can be applied to either analysis.

The curve of growth relates the equivalent width of an absorption line to the "number of active atoms," N, which produce it. For weak lines, theory indicates that W/λ is directly proportional to N through application of the Doppler principle to the velocity distribution of the atoms. As N increases, the line becomes saturated, the increase in intensity becomes less rapid and, on the "transition portion" of the curve, the intensity may remain almost constant for a time. Finally the natural breadth, which is important in the wings of a line, becomes more important than the Doppler "core," and the "damping portion," where $W/\lambda \propto \sqrt{N\gamma}$, is reached. γ, the damping factor, may be calculated from theory but it has been found that a value about ten times the classical value must be used in studies of the solar atmosphere. To explain this result, Unsöld[21] has shown that collisions between the atom and ions, electrons or hydrogen atoms are as important as radiation damping at pressures equal to those in the outer layers of the sun; however, for purposes of the theory, radiation and collision damping are additive and the square-root law still holds. It is known[22] that the damping constant may vary considerably from one multiplet to another, even for the same atom, but this has not been allowed for theoretically as yet, and a mean value has always been used in discussions of these phenomena.

For many stars it has been found that the Doppler motion of

[19] *Physik der Sternatmosphären*, Springer, Berlin, pp. 159-169; 264-273, 1938.

[20] *Tr. I. A. Un.*, vol. 6, p. 352, 1938.

*It should be noted that Unsöld's R_c refers to the absorption at the centre of a line and must not be confused with the more usual notation that r is the intensity ($= 1 -$ absorption) at any point on a line profile.

[21] l.c. p. 273.

[22] Minkowski and King, *Ap. J.*, vol. 95, p. 86, 1942.

the atoms corresponds to their thermal velocities at the excitation temperature of the star. This value, while usually below the effective temperature, is of the same order of magnitude. However, Struve and Elvey[1] found that for a few giant and supergiant stars, the velocities determined from the curve of growth are much larger than can be ascribed to thermal motion. Therefore they introduced an additional parameter, the "turbulent velocity," v, which may be produced by motions or currents in the atmosphere on a larger scale than the thermal motion. In extreme cases, the broadening of the lines should give a measure of the turbulent velocity but, even with high dispersion, the observed shape of a line is produced almost entirely by diffraction effects in the spectrograph, and the phenomenon is difficult to observe. However, it is readily understood that, for broad lines, saturation will not be reached until a larger number of atoms are effective. Therefore, the whole curve of growth will be raised and the flat portion will extend until the lines become further broadened in the wings, on the damping portion of the curve.

Theoretical curves of growth have been calculated by van der Held[23] and Minnaert and Slob[24] (using the classical theory of a radiating oscillator), by Menzel[25] (for the Schuster-Schwarzschild model of a purely scattering atmosphere), and by Unsöld[26] (for the same, but where re-emission, as expressed by $1\text{-}R_c$, is considered) for various values of Γ/ν and v.* To allow for possible turbulence, $\log (W/\lambda \cdot c/v)$ is plotted against $\log X_0$ for different values of $\log Z$, where $Z = \Gamma/\nu \cdot c/v$. Calculations may be made for the straight-line Doppler and damping portions of the curve, and an asymptotic formula is available for the transition portion,[27] but the three sections of the curve must be joined by mechanical means.

The curves of growth for α Persei shown in Figure 1 were fitted to the published families of curves after the latter had been re-

[23]*Z. f. Phys.*, vol. 70, p. 508, 1931.

[24]*Pr. K. Ak. Wet. Amsterdam*, vol. 34, p. 542, 1931.

[25]*Pop. A.*, vol. 47, p. 74, 1939.

[26]l.c., p. 268.

*γ refers to the theoretical damping constant, Γ to an empirical value; Γ/ν is assumed to be constant in order to simplify the theory. v is the velocity as determined directly from the curve of growth; if the thermal velocity is removed, the values will be decreased ~ 0.2 km./sec. for α Persei.

[27]See Menzel, *Ap. J.*, vol. 84, p. 464, 1936.

calculated where possible, transformed to the same coordinates, and re-drawn on the same scale. As the curves were determined empirically, it is not surprising that their agreement with the theoretical curves is not very good. The values of v and Γ/ν which give the best agreement between observational and theoretical curves for the three models mentioned above, are given in Table II. The differences may be considered a measure of the probable errors, and of the quality of fit between the curves. The curve for the ionized atoms gives a better fit for each model than that for the neutral atoms and, surprisingly enough, the former agrees very well for the

TABLE II. Constants for Empirical Curves of Growth Determined by Comparison with Theoretical Models

Model	Neutral Atoms		Ionized Atoms	
	v km./sec.	$\Gamma/\nu \times 10^6$	v km./sec.	$\Gamma/\nu \times 10^6$
van der Held	3.0	1.4	6.5	0.2
Menzel	3.7	0.7	6.4	0.2
Unsöld	3.1	0.7	6.8	0.4

classical model where pure absorption is assumed. As noted below, better agreement with the theoretical curves can be obtained from the observations but, as the effect now being studied has not been explained completely, the empirical curves are also presented here. The excellent agreement of the turbulent velocity for the ionized atoms indicates that a moderately good fit with the theoretical curves has been obtained. The values for the damping constant, Γ, cannot be considered definite as even the strongest lines in α Persei seem to be only at the beginning of the damping portion of the curve. However, on comparison with the solar curve, where Γ/ν was found to be 2.6×10^{-6}, these data may indicate that the damping constant for α Persei is between the classical and solar values. This suggests that damping due to collisions is less, corresponding to the lower pressure in a supergiant star.

In order to obtain the best values of v and Γ/ν that could be derived from the present theory, the individual plots of lines having the same excitation potential were fitted on Unsöld's curves. The

several plots for each atom were set on the family of curves and the best average value of c/v and Z was noted for each atom. They were then superposed for the value of the temperature calculated from equation (2); these theoretical curves for Fe I and Ti II are given in Figure 4. The plotted points correspond to normal places for each

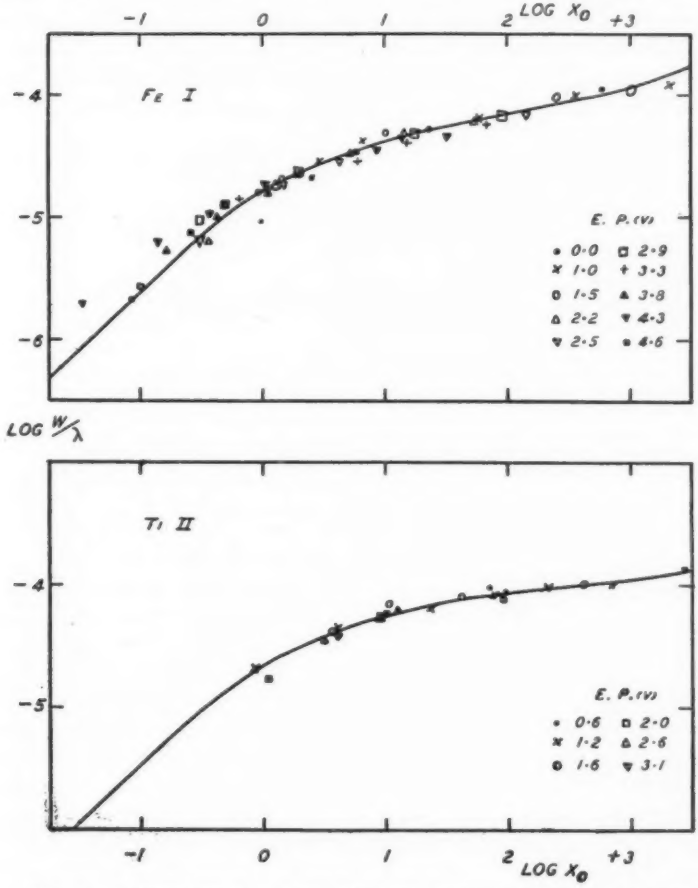

Fig. 4.—Observations of α Persei fitted on Theoretical Curves of Growth. a (above): normal places for observations of neutral iron separated according to ionization potential; b (below): normal places for ionized titanium.

excitation potential. The fit of the points on the theoretical curves is not as good as that on the empirical curves shown in Figure 1 but, in view of the elementary nature of the theory, it may be considered satisfactory. The results for T, Γ/ν and v, for those atoms where sufficient observations are available, are given in Table III. Of these quantities the variation in T may well be real but the probable errors are $\pm$ 200°; Γ/ν is somewhat indeterminate; however, v should be accurately determined as it is a measure of the height of the transition portion of the curve of growth. The difference between the velocities for Fe II and Ti II may be real, though an average value

TABLE III. Constants Derived from the Curves of Growth for Neutral and Ionized Atoms in the Spectrum of α Persei

Neutral Atoms					Ionized Atoms				
Atom	T_e °K	$\Gamma/\nu \times 10^6$	$v$km./sec.	No. of Lines	Atom	T_e °K	$\Gamma/\nu \times 10^6$	$v$km./sec.	No. of Lines
Fe I...	4950	1.3	5.0	325	Fe II...	4500	0.2	7.5	60
Ti I...	5600	...	3.9	53	Ti II...	5350	0.1	6.1	62
Cr I...	5350	1.6	4.6	29	Cr II...	5400	...	8.3	25
Ni I...	5100	2.1	5.2	54	Sc II...	5650	0.1	6.0	22
Ca I...	5550	1.1	4.0	30	Y II...	6650	...	11.6	16
Mn I..	4100	1.7	3.7	23	Ce II...	....	...	6.5	13
Mg I..	4850	1.1	4.2	10	V II....	....	...	5.8	9
Na I...	4850	1.1	4.1	7	Zr II...	....	...	5.1	6

was used for the empirical curves, but the fact that the turbulent velocity for Fe I is considerably below these values seems to be real.

These observations of α Persei seem to indicate a real difference between the curves of growth for neutral and ionized atoms. The difference shown by the curves of Figure 3 is certainly greatert han might be expected from observations of the accuracy which it is believed has been achieved in this study.* As further confirmation of this difference, the normal places for Fe I lines have been fitted onto the theoretical curve for Ti II in Figure 5. The observations

*In a letter of January 8, 1946, commenting on this paper, Dr. Struve notes that "Drs. Cesco and Sahade have recently completed a study of the curve of growth of γ Cygni..... Our tracings seem to indicate that there exists an effect similar to that which you have found in α Persei, although the amount is smaller....."

cannot be considered a satisfactory fit for this curve even when the usual probable error of ten per cent. is allowed.

A general summary of the results may be stated as follows: when lines produced by neutral and ionized atoms of the same element are compared, it seems that, for the neutral atom,

(1) the excitation temperature may be somewhat higher;

(2) the damping factor is probably greater — i.e. the pressure is higher;

and (3) the turbulent velocity is less.

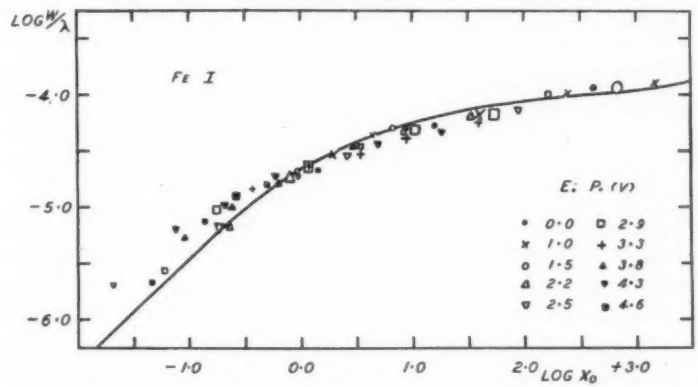

Fig. 5.—Observations of Neutral Iron in α Persei Fitted on the Theoretical Curve of Growth for Ionized Titanium.

A difference between the turbulent velocity for neutral and ionized atoms as derived from curves of growth should not be surprising, though until recently the observations were not sufficient either in accuracy or in quantity to detect the effect. Stratification in atmospheres of stars similar to the sun or of later spectral class has been suggested by various observers. From radial-velocity measures of lines in giant stars, Adams and MacCormack[28] observed that lines of neutral iron gave systematically larger negative velocities than lines of ionized atoms. This systematic displacement was 2.0 km./sec. for α Cygni and 0.71 km./sec. for γ Cygni; similar measures were made by the writer[29] in 1941 and displacements in the

[28] *Ap. J.*, vol. 81, p. 119, 1935.

[29] Unpublished: abstract in *Pr. Roy. S. Can.*, vol. 35, p. 171, 1941.

same sense of 0.46 km./sec. for γ Cygni and 0.31 km./sec. for α Persei were observed. St. John and Adams[30] explained this phenomenon as due to radial convection currents in stratified atmospheres. At low levels, where neutral atoms predominate, the currents have an upward motion, and at higher levels, the ionized atoms show a downward motion. Similar atmospheric motions have been studied in the spectra of Cepheid variables.[31] Stratification has also been observed during the eclipse of ζ Aurigae, by Christie and Wilson[32] and that of VV Cephei by Goedicke;[33] in each case it was found that ionized calcium and titanium atoms extended higher into the atmosphere than did neutral atoms.* Turbulence in such stars has not yet been measured, but in the case of the sun, it appears[34] that turbulence increases with height, from the reversing layer, through the chromosphere and out into the corona. In the chromosphere, Pettit[35] has observed that the velocity of a prominence increases with its height above the surface of the sun.

A second possible explanation for the shape of the curve of growth for supergiant stars has been suggested by Menzel,[36] who considers that, while turbulence is undoubtedly present in stellar atmospheres, other factors may be present to complicate the theory of the curve of growth. He suggested that the theory based on the formation of spectrum lines by absorption and scattering may not be adequate, and that emission and absorption processes may be more nearly balanced than the theory suggests; for a star with an extended atmosphere, the curve of growth may be some mean between a curve for pure absorption and one similar to that observed for emission in the chromosphere. Few stars of type F—G have been observed which have emission lines in their spectra, though bright

[30] *Ap. J.*, vol. 60, p. 43, 1924.

[31] See *P.O. Univ. Mich.*, vols. 4-6, 1920-34.

[32] *Ap. J.*, vol. 81, p. 426, 1935.

[33] *P. O. Univ. Mich.*, vol. 8, p. 1, 1939.

*In the solar chromosphere, flash spectra and observations with the spectroheliograph also indicate stratification in the atmosphere. The long arcs of the Ca II, H and He lines suggest a higher level for these atoms than the shorter arcs produced by metallic lines.

[34] ten Bruggencate, *Viert. A. G.*, vol. 76, p. 172, 1941.

[35] *Ap. J.*, vol. 84, p. 319, 1936.

[36] *Pop. A.*, vol. 47, p. 79, 1939.

hydrogen lines have been observed in one or two Cepheids.† Recently, Joy[37] discussed a new class of variable stars, the T Tauri stars of type F5 — G5, in which many emission lines are observed. In these, and also late-type emission-line stars, it is found that most of the emission occurs among the ionized atoms, chiefly Fe II and Ti II; the neutral iron lines which occur in emission are very much weaker, though, in each case, the strongest lines in emission are also those which appear strongest in absorption in α Persei.

As emission is usually considered to arise when suitable conditions of excitation occur in an outer shell of gas about a star—or in an extended atmosphere, which is very similar—Menzel's explanation of the curve-of-growth phenomenon as due to emission might be accepted qualitatively: The phenomenon should appear in the outer layers of the atmosphere where the ionized atoms predominate and the conditions of excitation are more favourable. As emission would be more important for the intrinsically stronger lines, it is possible that this emission would nearly balance the increased absorption for those lines and the observed intensity would remain almost constant over a considerable range in X_o. Then the curve of growth for neutral iron, which is lower in the atmosphere, could be considered as similar to that which is produced in stars with less extended atmospheres where emission is not important. But, although the long flat transition portion of the curve for ionized atoms may be explained qualitatively as due to excess emission, it is difficult to understand why the curve should follow the Doppler law to such large values of log W/λ as the observations seem to indicate, before going over to the transition portion of the curve. To explain this effect, it would appear that a combination of turbulence plus emission would be required, whereas the explanation as due to turbulence alone seems to explain the phenomenon.

The only other published data concerning possible differences in the curve of growth for different elements are those given by Aller.[38] He found that in α Cygni, Cr II and Ti II do not fit the curve of growth determined by the Fe II atoms, and suggested that inter-

†Emission lines superposed on the central portion of the broad absorption lines of Ca II (H and K) have been observed in the spectra of many G- and K-type stars.

[37] *Ap. J.*, vol. 102, p. 168, 1945.

[38] *Ap. J.*, vol. 95, p. 73, 1942.

locking or emission arising from chromospheric effects might explain the discrepancy. In an unpublished investigation in 1942, the writer also suggested that Ti II behaves differently from other atoms in α Persei and in γ Cygni, but the data were not definitive at that time. In order to study these phenomena more fully, further analyses of the spectra of α Canis Minoris and γ Cygni are planned.

The contents of this paper were presented before the American Astronomical Society in February, 1946. The author wishes to thank his colleagues at the Dominion Astrophysical Observatory for many helpful discussions and suggestions, and Dr. O. Struve and Dr. D. H. Menzel for a critical reading of the manuscript in advance of publication.

Dominion Astrophysical Observatory,
Victoria, B.C.
January 17, 1946.

REVIEW OF PUBLICATIONS

Water Adsorption—by Edward Ledoux. Preface by Donald F. Othmer, Polytechnic Institute, Brooklyn. 360 pages; fully illustrated, 1945. Chemical Publishing Company, Inc., Brooklyn, N. Y. Price $8.50.

Under the headings "Static Adsorption," "Saturation of Air," Dynamic Adsorption," and "Industrial Applications" the author has succeeded in giving a clear and concise account.

The relatively large number of illustrations (145) is indicative of the careful effort made by the author to present the subject matter in a form which would be most acceptable, and the cost of these is probably reflected in the price of the volume.

The author has wisely refrained from exploiting any particular theory and, regardless of developments in the near future, his work should remain a useful addition to the literature of this field and of particular interest to engineers.

JOHN B. FERGUSON.

German for the Scientist, by PETER F. WIENER. xxi, 238 pages. 4¾ x 7¼ in. Brooklyn, N.Y., Chemical Publishing Co., Inc.; Toronto, General Publishing. 1946, Price $4.90.

This is a useful and practical book. To the young graduate in science who wishes to go forward a reading knowledge of German is indispensable, and too many neglect to secure it during high school and undergraduate days. This little work has been compiled by capable hands for the purpose of supplying, in the most direct and economical way, an introduction to the reading of scientific texts in German.

The author was formerly a tutor in the University of London, but is now a teacher in Rugby School. The present American edition contains additional sections and a useful 'foreword' by Paul Spoerri of the Polytechnic Institute of Brooklyn.

In ten lessons (27 pages) is an effective grammatical introduction, which is followed by 24 pages of grammatical tables, abbreviations and sample passages from examination papers. There are 32 selections from Chemistry and Physics for practice. At the back are translations into English of these selections, and a vocabulary.

The price seems rather high but the student in urgent need of assistance will soon get the value from the book.

C. A. C.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Mount Wilson and Mount Palomar

Through the vision and the generosity of Andrew Carnegie the Carnegie Institution of Washington was founded in 1902. It consists of a number of outstanding research departments, among them being astronomy, biology, terrestrial magnetism, and others. At the beginning a committee of three astronomers—Lewis Boss, W. W. Campbell and George E. Hale—was appointed to consider the question of southern and solar observatories, and its report was published in December, 1903.

Professor W. J. Hussey was secured to make the actual investigations of various sites, and it will be interesting to quote from his report to the commitee. Of Mount Wilson, in the Los Angeles area, he remarks:

> I had been assured that Mount Wilson was very different from Mount Lowe, though from the valley it has the same grim outlines; but I was quite unprepared for the actual view of it. Instead of one barren rock, a succession of rolling knolls forms the summit. The canyons contain spruce and the ridges are covered with chaparral—a growth of Ceanothus (buckthorn), scrub oak and other evergreen bushes, so luxuriant, so dense, that passage through it is quite impossible without the aid of an ax. This appealed to me at once as an ideal covering, changeless the year round, for the checking of solar radiation.
>
> On exploration, Mount Wilson seemed to have in addition these points of advantage: A water supply remarkable for abundance and nearness to the summit; a small peak adjacent to and above the source of this water, somewhat higher than

Wilson's peak, which could be utilized for pressure in a water system; abundance of granite rock, both dark and light, some of it showing excellent cleavage, for building purposes.

The live oak is everywhere, both as tree and shrub, and in the canyons maple, alder, sycamore, bay, and cottonwood are found. Of the conifers, the big-coned spruce most abound; and it is to this and the chaparral that the mountain owes its unbroken slopes of green.

Of course tests were made of the atmospheric conditions, which were found satisfactory. Upon this mountain, at an elevation of 5,800 feet, was established the Mount Wilson Observatory in 1904. The present writer visited it in September 1907, at which time solar research was actively carried on, but the 100-inch telescope was not completed until some years later. This great observatory has attained great distinction in several branches of astronomy.

Among other sites examined by Professor Hussey was Mount Palomar in the San Diego region, and of it he remarks:

Nothing prepares one for the surprise of Palomar. There it stands, a hanging garden above the arid lands. Springs of water burst out of the hillside and cross the road in rivulets. The road is through forests that a king might covet—oak and cedar and stately fir. A valley where the cattle stand knee-deep in grass has on one side a line of hills as desolate as Nevada; on the other side, majestic slopes of pines.

In more recent years a wide search for a suitable site for the 200-inch telescope was made but nothing more suitable than Mount Palomar was found. The mounting of the giant instrument has been erected on it and let us hope that the monster mirror will soon be ready to be put in its place, to begin its work of exploration into the depths of space.

C. A. C.

New Reflector for the Lick Observatory

The following note, with its pleasing information, is from *Publications of the Astronomical Society of the Pacific* for April 1946:

On March 13 Governor Warren signed an appropriation bill passed by the state legislature which allotted $30,000,000 for the construction of buildings and equipment for the University of California. Included in this allotment is the sum of $1,200,000 for the construction of a large reflecting telescope for the Lick Observatory. Work on the design of this instrument has been started. The engineer in charge is Mr. Baustian,, recently supervisor of construction and maintenance

on an NDRC program at the Hydrodynamics Laboratory of the California Institute of Technology.

The design is proceeding on the basis of an aperture of 120 inches and a focal length of 50 feet (F/5), and every attempt will be made to secure an instrument of this size within the available funds. The mounting will probably be of the long fork type. The location that has been selected is on the main ridge of Mount Hamilton near the present tennis court, about one third of the distance toward Copernicus Peak from the main observatory buildings.

It may be appropriate to remark here that J. E. Keeler was director of the Lick Observatory from 1898 until his death August 12, 1900; and that his brilliant handling of the 36-inch Crossley reflector, a difficult instrument to observe with, and the remarkable celestial photographs he obtained, led to the great new era of reflecting telescopes which is still upon us.

C. A. C.

OUT OF OLD BOOKS

By Helen Sawyer Hogg

LAST month, in the first number of this new section, we reprinted some vivid descriptions of the coloured sky phenomena visible around the world after the gigantic eruption of Krakatoa in 1883. In at least one city on this continent the sunset glow was so brilliant that the fire department was called out to extinguish what appeared to be a conflagration.

The subject of Krakatoa and its resulting phenomena has been summarized in a massive and scarce volume under the auspices of the Royal Society, entitled *The Eruption of Krakatoa and Subsequent Phenomena,* edited by G. J. Symons; printed by Harrison and Sons, London, 1888. This splendid volume summarizes hundreds of descriptions and discusses the various aspects of the event under five headings. (I.) On the volcanic phenomena of the eruption, and on the nature and distribution of the ejected materials. (II.) On the air waves and sounds caused by the eruption of Krakatoa in August, 1883. (III.) On the seismic sea waves caused by the eruption of Krakatoa, August 26th and 27th, 1883. (IV.) On the unusual optical phenomena of the atmosphere, 1883-6, including twilight effects, coronal appearances, sky haze, coloured suns, moons, etc. (V) Report on the magnetical and electrical phenomena accompanying the Krakatoa explosion.

This volume is strongly recommended to our readers who wish to study the subject in detail. It would appear to be very timely just now, in view of the projected atomic bombing in the Pacific, to consider the important atmospheric and astronomical effects which result from the hurling of large quantities of dust into the earth's atmosphere.

The Royal Society volume does not summarize the accounts of telescopic meteors and floating particles which appear below. Since they are recorded by such experienced and distinguished observers as Professors Brooks and E. E. Barnard, they are worthy of consider-

ation. The account of a flight of telescopic meteors by Brooks is in the article "The Red Sunsets," by William W. Payne, Editor, in *The Sidereal Messenger,* vol 2, p. 294, Jan. 1884.

A Shower of Telescopic Meteors

In a letter from Professor William R. Brooks, Phelps, New York, under date of Dec. 8, 1883. He says: "While sweeping on the evening of November 28th, it was my pleasure to observe a wonderful shower or flight of telescopic meteors about ten degrees above the horizon, and near the sunset point. They were very small, none of them visible to the naked eye, most of them leaving a faint train, visible in the telescope for one or two seconds. The motion of most of them was to the northward, with an occasional group to the south of the Sun, moving southward.

This observation occurring at the time when the unusual red light phenomenon was at its height the theory is suggested of a possible connection between that phenomenon and the passage of the Earth through a mass of meteoric matter more or less attenuated.

Being deeply interested in the very remarkable observation, Professor Brooks was requested to give a drawing of what he saw which was kindly furnished for the *Messenger* and appears below.

Under date of Dec. 15, he further says: "As may readily be inferred, the wonderful sight is a difficult one to represent in a drawing; but I have endeavored to give some idea of the appearance at its maximum stage. The instrument used was a nine-inch reflector with comet eye-piece giving a field of one and one-half degrees. The field shown in the drawing was a few degrees north of the sunset point and about ten degrees above the horizon. The faithful comet seeker, frequently in a single night's work encounters numerous telescopic meteors, singly, very rarely two at once; but this flight is quite unprecedented in my experience."

Mr. E. E. Barnard, Nashville, Tenn., has given attention to these wonderful,

and, as he says, unaccountable phenomena. His first notes were made Oct. 29, and since that date, glowing sunsets have been seen quite constantly when the sky was favorable. From observations which cannot now be given, he thinks the cause lies in the upper strata of the atmosphere, though not at all certain of it. He confirms the observation first reported by Professor Brooks.

As late as Dec. 15, he saw with the telescope small bright bodies close to the Sun. They were visible at the rate of five or six per minute, and were all moving to the north of east quite rapidly. Occasionally a larger body was seen to flash across the field, blurred by being out of focus. Generally they looked like little stars, many as bright as those of the first magnitude. Mr. Barnard could follow the slower moving ones with the telescope for five or six degrees from the Sun, where they became faint and were lost. He was unable to detect any crossing the Sun; they seemed to be some distance from it, and required generally an increase of focal distance to see favorably. He thinks they are small particles drifting with the air currents at considerable altitude. He gives no definite opinion concerning the cause of the red sunsets.

This discussion is continued in *The Sidereal Messenger*, vol. 3, p. 18, 1884.

January 9. Mr. Barnard, Nashville, Tenn., was observing with the telescope in the immediate vicinity of the Sun, and saw numbers of small bright particles passing swiftly across the field. He says: "At 3 o'clock p.m. I caught a pretty bright one and followed it for a distance of ten degrees, horizontally towards the north. It was not round, it was not a point, very white; it grew dimmer and dimmer until it faded from view, at the above distance from the Sun. Power, fifty-two diameters. The focus of the instrument was adopted sharply to an object less than a mile distant. So whatever the object was, it could not have been more than a few hundred feet above the Earth."

Mr. Barnard further says: "There is scarcely a day but that these objects are visible close to the Sun."

There is a very general agreement among physicists and astronomers in the thought that these phenomena are caused either by volcanic or meteoric dust in the atmosphere.

From the September 1884 issue of the same journal, we read of Barnard's conclusion, as follows:

THE RED SKIES

If the phenomenon of our red skies is due to the volcanic eruption in Java, and the proof seems to point to that as a cause, my frequent observations of bright, rapidly-moving particles near the Sun can readily be explained, on the supposition that they were minute particles of ashes drifting through the atmosphere, which had their origin in the awful catastrophe of Krakatoa. Though great numbers of these floating bodies were visible in the instrument, the number too small to be seen must have been far greater. Around the Sun to a distance of 15°, the sky has

presented a greenish appearance. The outer border of this glare of light is always terminated by a brick-dust reddish ring, showing that the phenomenon of morning and evening attends the Sun for the entire day. During the first part of the year, the red glow preceded the rising of the full Moon, though of course not so conspicuous as in the case of the Sun, indicating that it does not exist simply in the direction of the Sun, for the full Moon appears almost constantly surrounded by a pearly glare, resembling that around the Sun.

E. E. B.

The atmospheric conditions, especially in the daytime, are a subject for discussion in an article in the October 1884 *Sidereal Messenger*:

Recent Peculiar Atmospheric Conditions

By J. R. Hooper, (Baltimore)

Having noticed during the last six months, an unusual amount of bad "seeing" and especially so in daytime, the cause became a subject of inquiry, and as a result, I beg leave to submit for record, the following notes which may also serve to call out other and more valuable observations.

At night, up to August, the power of the telescope to define has been very unsatisfactory, and in daytime there has been a constant and marked trouble in seeing even second magnitude stars. The unprecedented cloudiness of the first three months of the year, has greatly lessened the number of clear days usually enjoyed. When the clear skies came, the difficulty of doing such daytime work as I had formerly done, was noticed, and still exists at this time of writing.

I therefore raise this query: Is there a change in the atmosphere, or is there in it a foreign material which is capable of modifying the visibility of other than the brightest objects?

Every observer is acquainted with the deceptive "apparent" blue skies, but as bearing on the above query, I append a few data from my own observations made at 8 A.M. and 4 P.M. from April to August of the present year, as follows:

The marked trouble in seeing stars as bright as the second magnitude; frequently not seeing Alpha Andromedae when near the zenith at 8 A.M.

A corresponding indistinctness in first magnitude stars.

In following Mercury in 1883, I readily found him sixteen days after inferior conjunction, though in the Sun's rays, and I could see the crescent very neatly defined a week later.

In 1884, though searching carefully, it was thirty-one days after inferior conjunction before I could see the planet, and then it was five days after greatest elongation. At no time has the disk been fairly defined, while last year the reverse was the rule.

In all observations during these months, the definition of details of every kind on the Sun's face has been superior to that of last year. Hence, the idea comes to mind that there may be some substance in the air which diffuses the Sun's light

to an unusual degree, but does not affect the seeing at night, nor make bad definition for the Sun's surface. The stars may seem fainter because of the whiteness of the sky otherwise unnoticeable.

In January and February of this year, I sometimes noticed a peculiar pearly whiteness around the Sun before sunset, and outside of that a dingy reddish tint, the radius of the arc being from 20° to 30°. In March I began to see at midday, a complete halo of the same color, having a radius of about 20°. When the sky was very blue it was well defined, but on days when the whiteness was present it was not seen. In July I measured it on one occasion, and made the inner edge nine degrees from the Sun with a breadth of seven degrees.

In a letter to the *English Mechanic* for June 20, a Fellow of the Royal Society writes:

"As to the bad definition incident on the visibility of the after-glow, I should like to remark that for some time past, daylight definition of celestial objects has been worse than ever I remember it during my tolerably long observing experience.

Transit-taking in daylight, save with the large stars, has been quite impracticable, and over and over again I have looked in vain for Mercury. * * * Of course everyone who is in the habit of using a telescope in the daytime, is familiar with the fact that on many seemingly cloudless days there is an otherwise invisible kind of haze which impairs or destroys definition; and that the best and brightest vision is obtained in the blue sky visible below large floating Cumuli. But this curious obscuration has been just as apparent during the latter condition of the atmosphere as during the former."

These graphic accounts can certainly serve as a warning as to how much our atmospheric conditions may effect our astronomical observations.

MEETINGS OF THE SOCIETY

AT TORONTO

March 6, 1945—The Society met at 8:00 p.m. in the McLennan Laboratory, Mr. H. W. Barker in the chair.

One person was elected to membership in the Society, viz:

Mr. John W. Edwards, 305 Avenue Road, Toronto.

Prof. A. F. C. Stevenson of the department of applied mathematics, University of Toronto, presented a paper on the life of Sir Arthur S. Eddington whose death had recently occurred in England. After reviewing biographical details of Eddington's life and work, he discussed some of his contributions to astronomy and his philosophical ideas, and stressed particularly the British scientist's work on the physical constants.

The Chairman pointed out that Sir Arthur was one of two astronomers honoured by the Society a few weeks earlier when honorary life membership was conferred on him, and regretted that his untimely death likely had occurred before notification of the honour had reached England.

March 20, 1945—The Society met at 8:30 p.m. in Central School, Forest Hill Village, Mr. H. W. Barker presiding.

Mr. Edwin V. Greenwood, 17 Ruskin Avenue, Toronto, was elected to membership in the Society.

The audience then moved into the school's planetarium dome for a demonstration of the equipment. Mr. Rudolph Dunbar, of the "Peerless Planetarium," pointed out that the hemispherical shaped room, 21 feet in diameter and 15 feet high, could accommodate about fifty students, as well as the instructor and the projecting apparatus. Provision was also made for showing lantern slides or motion picture films in the darkened room.

With the lights turned out, Mr. Dunbar set the projector into operation and the familiar stars of a spring night appeared on the "sky" overhead. Then as he manipulated switches and levers, the entire sky appeared to revolve, demonstrating rising and setting of the stars. Next the watchers were taken, in effect, to the north pole; then to the equator and southwards, seeing varying skies as they would appear in the different latitudes.

The demonstrator illustrated the many uses of the apparatus in teaching astronomy and geography, successively producing eclipses, phases of the moon, explaining the causes of tides, and the reasons for seasonal variations in weather. A film was shown and Mr. Dunbar was besieged with questions before the interesting demonstration was concluded.

Tuesday, April 3, 1945—The Society met at 8:00 p.m. in the McLennan Laboratory; Mr. H. W. Barker presiding.

Miss Elisabeth Achelis, President of the World Calendar Association, New York, addressed the Society on "One World Calendar for One World." She was introduced by Dr. R. H. Coats, former Dominion Statistician. "The Calendar is a subject on which few of us know as much as we ought," he said. "The present calendar has serious drawbacks from the viewpoint of businessmen and many in the professions, and Miss Achelis in urging a moderate revision of the Gregorian Calendar is seeking to make the best of a bad job." Dr. Coats referred especially to his experiences while director of the Dominion Bureau of Statistics, in trying to get proper comparisons between statistics for months of varying lengths, and with different numbers of Sundays, working days, and Saturdays.

Miss Achelis spoke first on the history of the Calendar; then pointed out the inconveniences inherent in the present calendar, and outlined her reasons for urging adoption of the World Calendar. Not only would it promote international goodwill, she said, but would benefit business, science, education, labor and mankind in general.

(The address is printed in full in this JOURNAL, July-August 1945.)

Mr. Andrew Thomson of the Meteorological Service of Canada, thanked Miss Achelis for coming to Canada to address Centres of the Society in Toronto, Hamilton, London and Windsor. Turning to his own science, he said: "Sometimes when we look at weather records we think it odd that February always seems to have fewer hours of sunlight, for instance, than any other month. But it's not so strange when you take time to consider the incongruity in the length of February compared with the other months."

The Chairman suggested that, after listening to Miss Achelis' address pointing out the many advantages of an improved calendar, the audience might like to indicate whether it was in favour of endorsing adoption of the World Calendar. The vote was unanimous. It was then moved by Mr. T. H. Mason that the Executive should draft a resolution, putting into proper form this expression of approval, and that it be presented at the annual meeting of the Centre for official action. Carried.

Mr. Cyril Hallam, one of the founder members of the Society's Windsor Centre, was then invited to tell of the activities there. He first brought greetings from the Windsor members—"from the youngest Centre to the oldest." There was close liaison between the Windsor Centre and the Detroit Astronomical Club, with members attending each other's meetings, he said. The Windsor group was attempting to extend interest among younger people particularly by undertaking observational activities whenever possible.

April 17, 1945—The Society met in the McLennan Laboratory at 8:00 p.m., Mr. H. W. Barker in the chair.

Three persons were elected to membership in the Society, viz:

Mr. K. M. Clipsham, 97 Caithness Avenue, Toronto.
Miss M. McLeod, 1330 King Street West, Toronto.
Mr. John Edgar Sears, 26 St. Joseph Street, Toronto.

Dr. A. D. Misener of the department of physics, University of Toronto, then presented a paper on "Interstellar Space in the Laboratory." A synopsis follows:

"When we think of interstellar space we think of great distances, large areas with little matter, very empty and very cold although we cannot assign any particular degree either to the amount of matter or the temperature. We can produce in the laboratory all the conditions that exist in interstellar space except the vast distances." The speaker went on to explain the laboratory methods of attaining very low temperatures, and also low pressures. "If we believe the Second Law of Thermodynamics we must say the temperature of space is something above 0°K or —273.16°C. The record low temperature obtained by laboratory methods is 0.003°K. At ordinary temperature and pressure there are 2.7×10^{19} molecules per cubic centimetre. It is calculated that at 0.10°K, pressure 10^{-33} cm. of mercury, there would be one molecule in 16 cubic metres. At temperature 0.003°K, pressure 10^{-1000}, there would be one molecule in 5×10^{910} cubic metres which is the same as one molecule in 5×10^{20} cubic parsecs. If, as one estimate places it, the volume of the entire universe is 4×10^{27} cubic parsecs, then at this temperature and pressure (the laboratory lows) there would only be 200 million molecules in the whole universe. We know, however, that the temperature in interstellar space cannot be absolute zero because for years the stars have been radiating energy into space, therefore that space cannot be empty. The energy must be there, and if there is radiation, space must have warmed up."

Dr. Misener demonstrated some of the university's low pressure and low temperature equipment at the conclusion of the lecture.

Several members discussed the eclipse of the sun to take place in western Canada in July, and spoke of plans being made by some of the observing groups intending to go to Saskatchewan and Manitoba to view it.

FREDERIC L. TROYER, *Recorder*

The Royal Astronomical Society of Canada

OFFICERS FOR 1946

Honorary President—The Honourable George A. Drew, Prime Minister and Minister of Education for the Province of Ontario.
President—A. E. Johns, Ph.D., Hamilton, Ont.
First Vice-President—H. Boyd Brydon, Victoria, B.C.
Second Vice-President—J. W. Campbell, Ph.D., Edmonton, Alta.
General Secretary—E. J. A. Kennedy, 3 Willcocks St., Toronto 5
General Treasurer—J. H. Horning, M.A., Toronto
Recorder—H. W. Barker, Toronto
Librarian—D. W. Best, D.D., Toronto
General Council—S. C. Brown, Toronto; G. E. Campbell, M.A., Hamilton, Ont.; W. G. Cotgrove, M.A., B.D., London, Ont.; G. Harper Hall, Montreal, P.Q.; Cyril B. Hallam, B.A., Windsor, Ont.; Helen S. Hogg, Ph.D., Toronto; P. H. Nadeau, M.Sc., Quebec; Robert Peters, Victoria, B.C.; Andrew Thomson, M.A., Toronto; M. M. Thomson, B.A., Ottawa; H. D. Smith, Ph.D., Vancouver, B.C.; ———— Edmonton, Alta., and Past Presidents—F. S. Hogg, Ph.D., and A. Vibert Douglas, M.B.E., Ph.D.; also the presiding officer of each centre.

TORONTO CENTRE

Honorary President—C. A. Chant, Ph.D. *President*—H. W. Barker
First Vice-President—A. R. Clute, K.C. *Second Vice-President*—Frank S. Hogg, Ph.D.
Secretary—Tracy D. Waring, 44 Rose Park Drive, Toronto 12
Treasurer—T. H. Mason *Recorder*—Frederic L. Troyer
Council—J. F. Heard, Ph.D.; George T. Dale; R. S. Duncan; S/L P. M. Millman; J. H. Horning, M.A.; H. G. Duncalfe; Helen S. Hogg, Ph.D.; C. A. Crook; W. R. Sherrick; and Past Presidents—J. R. Collins; E. J. A. Kennedy; S. C. Brown; Rev. D. W. Best; Miss R. J. Northcott, M.A.

OTTAWA CENTRE

Honorary President—T. L. Tanton, Ph.D. *President*—Hoyes Lloyd, M.A.
First Vice-President—F/L M. M. Thomson, B.A.
Second Vice-President—R. J. McDiarmid, Ph.D.
Secretary—W. S. McClenahan, B.A., Dominion Observatory, Ottawa
Treasurer—F. W. Matley, Esq.
Council—Miss C. B. Hicks, B.A.; R. G. Madill, B.A.; A. H. Miller, M. A.; Valmer A. Nixon; C. B. Reilly, K.C.

HAMILTON CENTRE

Honorary President—W. T. Goddard *President*—Rev. E. F. Maunsell
Vice-President—T. M. Norton, 225 Young St., Hamilton, Ont.
Secretary-Treasurer—G. Murchie *Curator*—Mr. G. E. Campbell, M.A.
Council—Dr. W. Findley; Dr. A. E. Johns; W. D. Stewart, B.A.; D. G. Burns; F. S. Sisman; W. S. Mallory, M.A.; H. B. Fox; J. W. McCallion, B.A.; F. H. Butcher, B.A.; J. R. Graham; F. Schneider; V. Taylor.

WINNIPEG CENTRE

Honorary President—Prof. L. A. H. Warren *President*—Miss O. A. Armstrong
First Vice-President—A. P. Morse *Secretary*—C. G. Card, 1197 Dominion St.
Treasurer—C. D. Dorsett *Press Secretary*—L. W. Koser
Council—L. J. Crocker; Mrs. J. Norris; R. A. Storch; D. R. P. Coats; L. T. S. Norris-Elye; V. C. Jones.

MONTREAL CENTRE

Honorary President—Mgr. C. P. Choquette *President*—Henry F. Hall
Vice-President—F. J. DeKinder
Secretary—J. W. Duffie, Room 701, Windsor Station, Montreal 3
Treasurer—A. R. MacLennan *Recording Secretary*—Miss I. K. Williamson
Director of Observations—DeLisle Garneau *Librarian*—C. M. Good
Council—Dr. D. E. Douglas; G. Harper Hall; F. W. Henshaw; Prof. A. H. S. Gillson; F. T. Matthews; F. P. Morgan; R. Russell Paterson; Dr. W. Bruce Ross; Dr. A. Norman Shaw; and Past President—Dan. P. Gillmor, K.C.

VICTORIA CENTRE

Honorary President—R. M. Petrie, Ph.D. *President*—K. O. Wright, Ph.D.
First Vice-President—A. McKellar, Ph.D. *Second Vice-President*—W. R. Hobday
Secretary-Treasurer—Miss J. K. McDonald, B.Sc., Dom. Astrophysical Observatory
Recorder—Lt.-Cmdr. A. M. P. Scaife *Librarian*—Miss V. Langworthy
Council—H. J. Chalk; Mrs. J. R. Noble; H. A. Reid; Dr. J. S. Stevenson; M. Trueman; Mrs. C. S. Yarwood

LONDON CENTRE

Honorary President—Dr. H. R. Kingston *President*—Dr. R. H. Cole
Vice-President—Dr. A. J. Watt *Secretary-Treasurer*—A. Emsley, 831 Richmond Street
Council—W. E. Shales; Dr. L. M. Spratt; Dr. G. Calder; Chas. Hanson; Mrs. D. M. Hennigar

VANCOUVER CENTRE

Honorary President—Dr. G. M. Shrum *President*—Dr. H. D. Smith
Vice-President—N. Barton *Recording Secretary*—C. D. Maunsell
Secretary—Margaret S. George, 4407 West 13a Ave. *Treasurer*—Miss G. W. Owen
Council—E. M. Price; Mrs. C. A. Rogers; Mrs. W. D. B. Phillips; Mrs. G. T. Gilpen; A. Outram; B. Catterall; Mrs. Anderson.

(Continued at bottom of next page)

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
1890-1946

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton, London and Windsor, Ontario; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as over 1,000 members of these Canadian Centres, there are over 400 members not attached to any Centre, mostly resident in other nations, while some 50 additional institutions or persons subscribe to our publications.

The Society publishes a monthly "Journal" containing about 500 pages and a yearly "Observer's Handbook" of 80 pages. Single copies of the "Journal" or "Handbook" are 25 cents, postpaid. In quantities of 10 or more copies, the price is 20 cents a copy.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 3 Willcocks St., Toronto.

The Society has for Sale:

Reprinted from the "Journal" of the Royal Astronomical Society, 1936-1944.

The Physical State of the Upper Atmosphere, (revised 1941) by B. Haurwitz, 96 pages; Price 75 cents postpaid.

General Instruction for Meteor Observing, (revised 1940) by Peter M. Millman, 24 pages; Price 15 cents postpaid.

A Yoke Mounting for the Six-inch Telescope, by H. Boyd Brydon, 8 pages; Price 10 cents postpaid.

Setting Up and Adjusting the Equatorial Reflecting Telescope, by H. Boyd Brydon, 25 pages; Price 25 cents postpaid.

Occultations: their Prediction, Observation and Reduction, by H. Boyd Brydon, 76 pages, 1944; Price 60 cents.

In quantities of ten or more copies, a discount of 20 per cent will be allowed. Send Money Order to 3 Willcocks St., Toronto.

(*Continued from previous page*)

EDMONTON CENTRE

Honorary President—J. W. CAMPBELL
Past President—M. WYMAN
Vice-President—F. C. BLOWER
Secretary—E. H. GOWAN, University of Alberta
Treasurer—MISS A. M. P. SMITH
Librarian—E. S. KEEPING
Social Hostess—MISS M. BOWMAN
Council—A. J. COOK; D. B. SCOTT; H. J. MONTGOMERY; T. M. CARSCADDEN.

CENTRE DE QUEBEC

Patron—MGR. FERDINAND VANDRY, P.A., V.G., Recteur de l'Université Laval
Président Honoraire—ARTHUR AMOS, I.C.
Président—JEAN-CHS. MAGNAN, B.A., B.S.A.
1er Vice-Président—LUCIEN POULIOT, C.G.A.
2ème Vice-Président—LIONEL LEMIEUX, B.A., LL.L.
Secrétaire—PAUL-H. NADEAU, M.Sc., 275 rue St. Cyrille
Trésorier—LIONEL GALLICHAN
Membres du Conseil—M.M. L'ABBÉ ROSARIO BENOIT; L'ABBÉ EMILIEN GAUTHIER; ALBÉRIC BOIVIN, B.Sc.Ap.; M.-LOUIS CARRIER, I.C.; GEO.-E. GAGNÉ; CHARLES-A. GIROUX; LLOYD MCWILLIAMS, EL.E.; OSCAR VILLENEUVE, I.F.

WINDSOR CENTRE

President—CYRIL B. HALLAM, B.A.
Vice-President—D. C. BAWTENHEIMER
Past President—C. H. MONTROSE, B.Sc.
Treasurer—CHARLES A. BELL, B.A.
Secretary—RUSSELL WARWICK, B.A., 1587 Moy Ave., Windsor, Ont.
Council—MRS. MARGARET BACK; JUDGE J. J. COUGHLIN; E. J. EDWARDS; JACK EVZOVITCH, B.S.E.E.; W. ALMON HARE, B.A.Sc.; F. W. C. JONES; E. M. KREBSER; GREGORY RAWLINGS, B.A.; W. A. ROBERSON; LORNE R. ROGERS, B.A.; G. F. SPRACKLIN; GORDON E. TURNER.